

REPORT DOCUMENTATION PAGE

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Final Technical Report

Title: DURIP 99 High Repetition Rate Laser Vaporization Source for Cluster Ion Beam
Deposition

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Objective:

This grant was to allow development of a high repetition rate, laser vaporization source for metal cluster ions, to be used in cluster deposition experiments. The project included acquiring a 100 Hz laser and fabricating a source assembly with computer-controlled target motion.

Results:

We purchased a Spectra-Physics LAB-190-100 laser system, including doubling system. The total cost of this laser was \$77,500, including a \$9200 discount. This cost was roughly \$10,000 greater than anticipated in the proposal budget, due to a manufacturer's price increase. Only Coherent Inc. sells a competitive commercial laser, but theirs is over \$120,000. I also evaluated a laser from Continuum, but it would have been a custom laser, based on a non-standard design. I felt that it was most important to get a proven design. We were able to offset the increased laser cost by saving on the pumping system and computer interface (electronics labor was provided by the department as cost sharing).

The laser produces about 140 mJ/pulse at 532 nm, which is more than adequate for laser

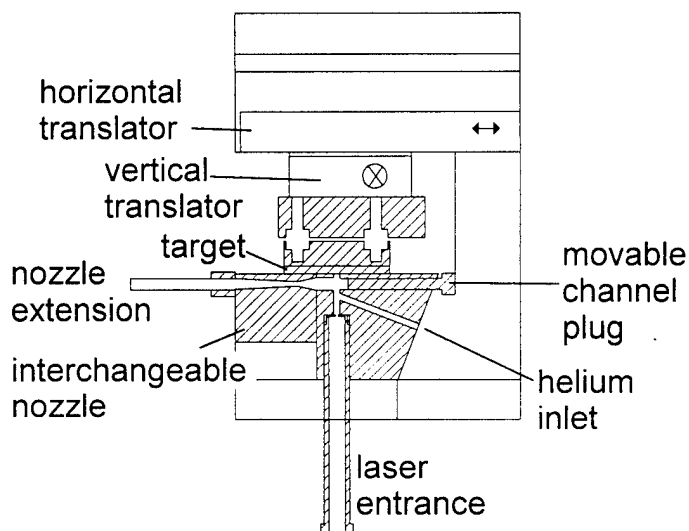
vaporization. Because the laser needs to be run at full power to maintain good beam quality, we also constructed an attenuator consisting of two sets of quartz flats, mounted on counter-rotating turntables. By varying the number of flats, and their angle with respect to the beam, variable attenuations ranging from ~10% to more than 80% can be set. Because the plates counter-rotate, there is insignificant beam walk as the attenuator is adjusted.

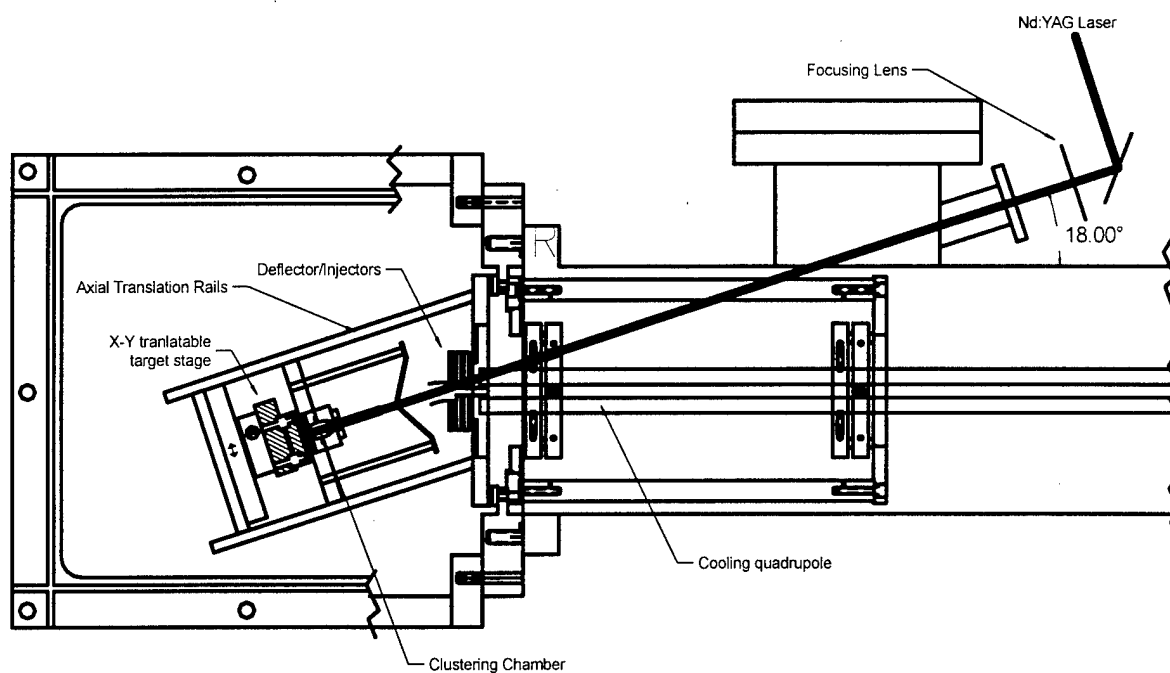
As proposed, several laser vaporization sources were developed and tested with a wide variety of transition metal and aluminum targets. At

right is shown the details of a transverse source (i.e., the laser is transverse to the beam axis). All sources are designed to work with planar targets, and share the same computer-controlled x-y stage that controls target position. This approach was used, rather than the more common rotating rod or disk target arrangement, so as to allow more efficient use of foil targets cut from expensive metals such

as iridium, palladium or gold. For example, iridium, of interest to the Air Force as a monopropellant decomposition catalyst, sells for ~\$600 per square inch of 0.5 mm foil. The ability to use the entire rectangular target will save considerable expense.

The transverse source is designed with the buffer gas flow merging with the laser channel, just above the target, and we have found that this arrangement reduces gas out-flow through the laser channel. The source also includes a moveable plug that allows the residence time and flow behavior to be modified. Finally, the source is constructed with interchangeable nozzle blocks, that allow the diameter, length, and type (e.g. straight v.s. converging-diverging) of nozzle to be varied. This source was developed prior to arrival of the 100 Hz laser, and found to work very well with a wide variety of metals

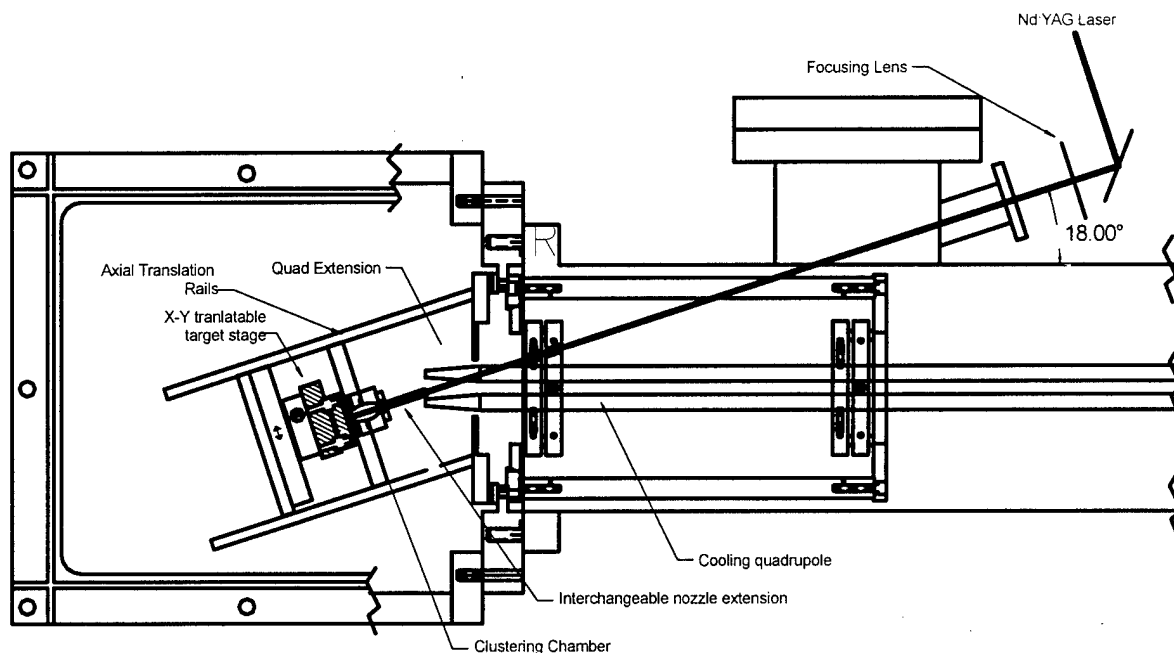




at 10 Hz.

Unfortunately, at 100 Hz, the transverse source performs poorly, probably because the high residual gas pressure in the source results in altered flow behavior. Certainly, we observe substantially more out-flow of buffer gas and metal through the laser entrance channel, leading to reduced intensities and rapid clogging. To avoid this problem, a second source was constructed as shown in the second figure (above). This source is a co-axial design, i.e., the laser counter-propagates along the cluster beam. The advantage to this arrangement is that the need for a separate channel to admit the laser beam is eliminated. The disadvantage to a coaxial design is that it is necessary to bend the cluster ion beam to allow passage of the laser beam. The most common approach to beam bending is to insert a 90° quadrupole bender in the ion beam, well downstream of the source, and this has been done by a number of groups for various applications in ion spectroscopy. We decided, instead, to try bending the beam at injection, reducing the bend angle to the minimum required to admit the laser. The figure above shows the original configuration, with a pair of deflection plates and three ion lenses designed to bend and focus the beam. The lenses also serve as a differential pumping wall between the source, and first quadrupole

ion guide. The ion optical problem at this point is quite complex, however, because there is a high density of ions, electrons, and buffer gas at the nozzle exit.

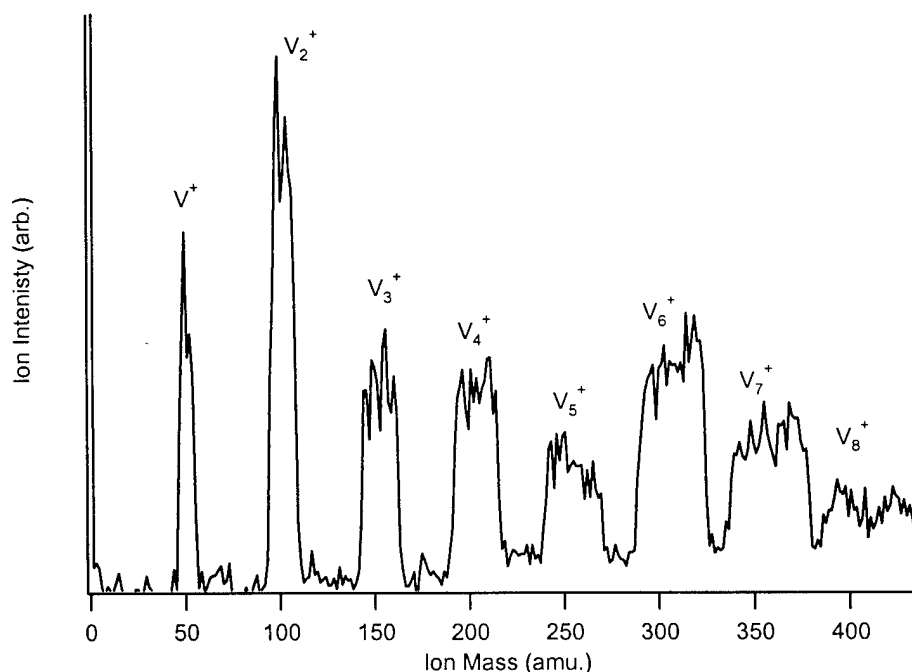


We have found that the best cluster intensities are gotten by dispensing with all ion optics, extending the quadrupole, and moving the source forward such that the nozzle is inserted directly into the entrance of the quadrupole, as shown in the third figure. To accommodate the nozzle, the quadrupole extensions are tapered. This arrangement results in very high peak pressures in the quadrupole, but we have experienced no problems with discharges. To help trap ions, the quadrupole rf-fields are augmented by four rod-shaped electrodes that are inserted in the gaps between the quadrupole rods in the extension section. The original idea was to apply a differential DC voltage across the extension that would act to deflect ions into co-axial trajectories. It is found, however, that the best intensities are achieved by biasing these supplemental electrodes all positive with respect to the quadrupole center line. In this mode, the quadrupole entrance looks to the ions more like an octapole field, and the centerline potential is shifted positive with respect to the main quadrupole. The steep effective potential walls resulting from

the octapole field appear to improve trapping of the injected cluster ions, and the positive centerline potential helps inject ions from the extension into the main quadrupole. We are still experimenting with modified injection schemes, although it is important to note that the intensities are already adequate for deposition experiments with many transition metals.

An example cluster intensity is shown in the final figure, for a vanadium target. This spectrum was taken with our 10 Hz laser, because the 100 Hz laser was down with optical damage. The damage was simply a minor coating burn on one of the YAG rods, probably resulting from a water leak. Unfortunately, it seems that the YAG rod business is very good these days, and it took more than six weeks to get the rod re-polished. If the problem is repeated, we will consider buying a spare rod to cut the down time. The repaired head was just returned by Spectra Physics last week and will be installed in the next few days.

The intensity scale on the figure translates into a current density of about 10 nA/cm^2 , or 10^{11} ions/sec/cm². If we take 10 % of a monolayer in one hour as our limit on required cluster intensity, the 10Hz source is already intense enough to allow deposition of clusters of up to 6 - 7 atoms. With the



increase in intensity resulting from 100 Hz operation, we should be able to deposit up to clusters of ten or more atoms. I am quite confident that there are intensity gains of a factor of five or more to be gotten from further tweaking of the cluster source, injection, and mass selection details. For improved mass selection, we recently ordered a new rf-generator for the mass-selecting quadrupole and redesigned the ion optics around it, based on extensive trajectory simulations. These modifications will extend the mass range to > 3000 amu, and should improve transmission.